MANAGING BRONZE BEETLE (*EUCOLASPSIS* SP.) IN HAWKE'S BAY ORGANIC APPLE ORCHARDS USING SOIL CULTIVATION

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ABSTRACT

Bronze beetle (*Eucolaspsis* sp., Coleoptera: Chrysomelidae) threatens the economic viability of New Zealand's organic pipfruit industry. Small plot cultivation trials were conducted during spring to target immature beetles in the soil under apple trees. These treatments did not appear to be as effective in the second year as in the previous year, although two cultivations significantly reduced beetle emergence at all orchards compared with the control. In large-scale cultivation trials, two cultivations reduced damage to apples by 46–61%. Sampling immature development stages of the beetles in the soil indicated that cultivation should commence during mid October to target pupae in the top 70 mm of the soil. The application of cultivation treatments for controlling bronze beetle on commercial orchards is discussed. **Keywords:** bronze beetle, organic apple production, cultivation, Chrysomelidae.

INTRODUCTION

Bronze beetle (*Eucolaspsis* sp., Coleoptera: Chrysomelidae) is an increasing problem in organic apple orchards, particularly in Hawke's Bay, with feeding by adult beetles on fruit resulting in up to 50% of apples at harvest being damaged in the worst affected orchards (Rogers et al. 2006, 2007). Bronze beetle is continuing to spread to previously unaffected blocks within orchards and to other orchards within Hawke's Bay, and recently an organic apple orchard in Nelson has been severely infested (P.W. Shaw, pers. comm.). Crop losses in high bush blueberries from cap stem chewing by adult bronze beetle has also been reported in Waikato (L. Hawes, pers. comm.). In apple orchards bronze beetle larvae feed below ground on the small roots of grasses (Miller 1971; Kay 1980), before emerging as adults to feed on apple leaves and fruit. Preliminary soil sampling during 2005 suggested that few bronze beetle larvae were found in the middle of the grassed alleyway between rows of apple trees and that the majority of larvae were found in the soil directly under the branches of apple trees (Rogers et al. 2006).

There are currently no effective, organically acceptable insecticides to control this pest. Historically soil cultivation has been used against bronze beetle (Lysaght 1930) and to manage other soil-dwelling Coleoptera (Gednalske & Walgenbach 1984). In small plot cultivation trials, Rogers et al. (2007) demonstrated that 79–95% control of beetles could be achieved. The present study followed on from that work and sought to determine the effectiveness of large-scale cultivation as a control strategy against immature beetles and to investigate whether cultivation in spring of one year influenced beetle emergence the following year.

METHODS

Sampling larvae and pupae

To determine when pupae were close to the surface and hence vulnerable to physical injury from cultivation, spade-square soil samples (18 cm wide, 280 mm deep), each less than 1 m from the base of an apple tree trunk, were dug from blocks of 'Royal Gala' trees, at three Hawke's Bay organic orchards (Orchards A, B and 2). Five samples were collected weekly from each block on six occasions from 13 September 2007. The samples were divided into 0–70 mm deep and greater than 70 mm deep fractions and hand-sorted to search for larvae and pupae.

Small-scale cultivation trials

The small plot cultivation trial comprised four tillage treatments and an untreated control, each applied to 10-tree plots within rows of apple trees. A randomised block design was used and each treatment was replicated three times at each of four orchards. In 2006 the plots were cultivated by a tractor-mounted Howard rotary hoe (540 rpm) along each side of the tree line (two passes) and between trees with a small domestic rotary hoe, as described by Rogers et al. (2007). The 2006 plots were not cultivated during 2007. In 2007 a new set of plots was established at the same site and a small commercial rotary hoe (SEP Italy, 230 mm tilling width) was used to achieve a fine tilth (four passes) (Table 1). In each case the soil was cultivated to a depth of approximately 7 cm. Beetle emergence was monitored weekly from 3 October 2007 to 3 January 2008 using five bucket emergence traps per plot (Rogers et al. 2006).

TABLE 1: Cultivation treatments applied to the small plots on four Hawke's Bay organic orchards.

Treatment	Description
Control	Untreated grass/weeds – mown prior to placing traps
2007 single cultivation	Cultivated once between 11–18 October 2007.
2007 two cultivations	First cultivation between 11–18 October 2007 and again 3 weeks later.
2006 single cultivation	Cultivated once between 29 September–10 October 2006. No cultivation during 2007.
2006 multiple (5-6) cultivations	First cultivation between 29 September and 10 October 2006 and then fortnightly. No cultivation during 2007.

Large-scale cultivation trial

Large areas of mature 'Royal Gala' apple trees within two orchards (B and C) were cultivated using a purpose-built commercial cultivator that operates like a swing-arm mower and is able to cultivate between trees as well as along a 1-m strip parallel to the row. This cultivator was equipped with pegs, rather than standard rotary hoe tines, designed to prevent the formation of hard pans within the soil. The areas were cultivated during mid October and again after about three weeks. A similar area within another orchard (A) was cultivated once on 31 October using a modified tine-type rotary hoe. In all cases the cultivated blocks were at least 70 m wide by 100 m long and at each orchard were compared with much smaller untreated (control) areas at least 20 m wide by 40 m long. Assessments of beetle damage to 50 bottom tier fruit from each of 20 trees per treatment as described by Rogers et al. (2007) were carried out in mid November

(pre-thinning) and mid January 2008 (pre-harvest). The monitoring sites within treated and untreated areas were at least 50 m apart.

Beetle distribution between rows

To determine distribution of bronze beetle in the inter-row area, three replicates of seven bucket emergence traps were positioned at one orchard, 83 cm apart (centre of trap to centre of adjacent trap) from the tree-line of one row, across the grassed alleyway to the tree-line of a neighbouring row (a distance of 5 m). The trap locations were categorised as: tree-line left, between tree-line & left wheel track, left wheel track (tractor wheel track), middle of alleyway (centre between the rows), right wheel track, between tree-line & right wheel track, tree-line right. These traps were kept in the same location for 4 weeks from 9 November 2007 and were monitored weekly.

Data analysis

Cultivation trial data were analysed separately for each orchard and differences compared by ANOVA followed by Tukey's HSD. Model adequacy checks were carried out by examining various plots (scatter, histograms and normal probability) of the residuals.

RESULTS

Sampling larvae and pupae

Over the sampling period larvae were found above and below a soil depth of 70 mm, although they tended to be more numerous above that level. This became more pronounced as the larvae developed to pupae, which were almost always found within 70 mm of the surface (Figs 1a & 1b). Predictably the number of bronze beetle pupae progressively increased from late September and early October at all orchards (Fig. 1a).

FIGURE 1: Mean ($\pm$ SEM) number of bronze beetle larvae and pupae found per spade-square soil sample from two depth zones, (A) less than 70 mm and (B) 70-280 mm. Data were combined for three Hawke's Bay orchards, from Orchard 2 (small-scale cultivation trial orchard) and Orchards A and B (large-scale trial orchards) in 2007.

Small-scale cultivation trials

The numbers of beetles caught in the control traps were highly variable and lower than expected (Table 2). The numbers of beetles collected from the single cultivation treatment at Orchards 2 and 3 were significantly lower than the numbers collected from the control treatment within the same orchard (Table 2). In addition, the values for the double cultivation at all orchards were significantly lower than the control treatment value. The 2006 cultivation treatments appeared to have had no significant impact on beetle numbers emerging in summer 2007-08, although fewer beetles emerged from these treatments at Orchard 4.

TABLE 2: Mean $\pm$ SEM cumulative numbers of bronze beetle adults caught per trap in the small scale cultivation trials from 3 October 2007 to 3 January 2008. Means followed by the same letter within columns are not significantly different (Tukey’s HSD, $P<0.05$).

Treatment	Orchard			
	1	2	3	4
Control	26.4 $\pm$ 8.8a	15.1 $\pm$ 4.0a	12.3 $\pm$ 1.5a	22.6 $\pm$ 4.8a
Single cultivation	15.7 $\pm$ 5.6a	2.8 $\pm$ 1.2b	2.1 $\pm$ 0.5b	4.2 $\pm$ 1.7a
Two cultivations	5.1 $\pm$ 0.9b	1.4 $\pm$ 0.5b	2.5 $\pm$ 0.2b	2.1 $\pm$ 1.4b
2006 single cultivation	19.2 $\pm$ 2.1a	13.6 $\pm$ 4.0a	15.9 $\pm$ 4.4a	9.3 $\pm$ 4.8a
2006 multiple cultivation	20.5 $\pm$ 3.7a	19.5 $\pm$ 4.5a	17.9 $\pm$ 6.5a	10.8 $\pm$ 1.5a

Large-scale cultivation trials

Cultivation of large areas within the orchards significantly reduced damage to fruit when compared with the control treatment at Orchards B and C when damage was assessed in November prior to thinning (Fig. 2). The percentage of damaged fruit in cultivated and control areas increased between the November and January assessments, but in January there were again more fruit damaged in the control areas than in cultivated areas in Orchards B and C (Fig. 2). Differences were not apparent between treatments at either date at Orchard A for the proportion of fruit damaged (Fig. 2).

FIGURE 2: Mean ($\pm$ SEM) percent damage caused by bronze beetle to apples in cultivated and uncultivated control areas in three Hawke’s Bay organic apple orchards in mid November 2007 and mid January 2008. Significant ($P=0.05$) treatment differences for each orchard are denoted by an *.

Beetle distribution between rows

Most beetles were collected from under trees close to the trunks, followed by the area between the trees and the vehicle path. No beetles emerged from the vehicle tracks and only one beetle emerged from the grassed area between tracks (Table 3). The data were very variable, however, and the only significant differences found were between under one tree line (left) and both vehicle tracks ($P < 0.05$).

TABLE 3 Mean $\pm$ SEM cumulative bronze beetle catch per trap, from mid November to mid December 2007, at a Hawke's Bay organic apple orchard.

Trap position	Cumulative bronze beetle catch
Tree-line left	19.0 $\pm$ 9.2
Between tree-line & L. wheel track	4.33 $\pm$ 3.3
Left wheel track	0
Middle of alleyway	1.00 $\pm$ 0.58
Right wheel track	0
Between tree-line & R. wheel track	5.00 $\pm$ 3.51
Tree-line right	8.33 $\pm$ 3.38

DISCUSSION

Rogers et al. (2007) concluded that cultivation during spring was a very successful control measure for reducing bronze beetle numbers in small plots. In part this is because the beetles move close to the surface of the soil prior to pupation and are vulnerable to mechanical damage from cultivation. Sampling of larvae and pupae in the present investigation supported this conclusion. The small-scale cultivation trials reported here were not as effective at reducing bronze beetle emergence but did significantly reduce beetle numbers in all plots that were cultivated on two occasions compared with the untreated controls. Cultivation on one occasion was not as effective as two occasions, although still resulted in significant reductions compared to the control plots at two of the four orchards. Beetle catches in the 2007 control traps were extremely variable and much lower than Rogers et al. (2007) reported. This may be partly due to very large cracks appearing in the soil under many of the buckets as a result of soil drying during the serious drought in Hawke's Bay during 2007. These cracks were covered by turf/leaf litter and were not easily visible, but may have enabled bronze beetle to escape, thereby explaining the apparently low control results. Cultivated plots would not have been subject to soil cracking. Field observations of beetle numbers and damage within the control plots during 2007 were similar to 2006 levels, suggesting low 2007 trap catch was not merely caused by different population levels.

When large blocks were cultivated in two orchards, there were significantly fewer bronze beetle-damaged fruit in these areas than in the control areas, in both November and January, suggesting that cultivation had had a positive influence in reducing fruit damage. Achieving successful control of bronze beetle with soil cultivation requires tilling to at least 70 mm, obtaining a fine tilth, and cultivating at least twice when pupae are the predominant development stage present (Rogers et al. 2007). The importance of these factors was illustrated in Orchard A, which was only cultivated once on 31 October, where a reduction of damage to fruit was not achieved in January prior to harvest. Observations at other orchards where cultivation was used to control bronze beetle corroborate that the quality and timing of the cultivation influences the outcome and that it can be difficult for growers to achieve a good result. The results Rogers et al. (2007) achieved suggest a greater reduction in bronze beetle populations in the large areas cultivated in this investigation could have been anticipated. A possible factor in the poorer than expected result could be that the pegs on the cultivators did not achieve

a tilth as fine as that obtained with standard rotary hoe tines. The results from sampling beetle emergence on the vehicle access-way suggest that even though this area was not cultivated, very few beetles would emerge from it or similar areas to contribute to damage. Soil sampling during 2007 indicated that the ideal time to cultivate for control of bronze beetle was mid October when a high proportion of pupae were found within the top 70 mm of the soil prior to adult emergence. Comparison of 2006 (Rogers et al. 2007) and 2007 soil sampling suggests that the 2007 bronze beetle population was about 1-2 weeks later in their development. This was reinforced by the results of adult trapping for 2006/07 (Rogers et al. 2007) and this investigation (2007/08) and indicates that monitoring of bronze beetle development will be necessary to optimise the benefits of cultivation as a control measure. This investigation has provided more evidence that cultivation is a promising strategy for the management of bronze beetle in organic orchards.

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